INCREASING OF RFID SYSTEM READ RANGE

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Summary This paper describes some computations needed to increase RFID system read range twice without any changes in RFID reader. The increasing of read range is done only by proper selection of RFID marker parameters – coil diameter and number of turns. Another way – generating stronger magnetic field from reader – can not be used because requirements of some limitations given by valid standards must be taken into account.

1. INTRODUCTION

Two years ago the papers [1] and [2], which describe solution of some technical problems of digital RFID marker and reader (locator) development were published. Parameters of developed locator are fully comparable with similar equipments produced in USA and Germany. Marker can be located from distance of 2 m and identification code from RFID chip in marker can be read from distance of 1.5 m.

This paper analyzes possibilities how to increase the read and localization ranges twice (from 1.5 m to 3 m) because some engineering networks (mostly water and sewerage pipes) marked by RFID markers are buried more than 3 m under ground surface. At the same time valid standards which limit magnetic field intensity generated by locator must be observed so that the equipment could be operated under General License VPR-06/2005 issued by Telecommunication Office of Slovak Republic.

2. LIMITS FOR THE RADIATED MAGNETIC FIELD

For RFID applications in used frequency band from 80 to 150 kHz next standards and regulations are accepted:

- General License VPR-06/2005 issued by Telecommunication Office of Slovak Republic
- Recommendation ERC/REC 70-03, annex 9, issued by ERC (European Radiocommunications Committee)
- Decision ERC/DEC/(01)13 issued by ERC
- Standard ETSI EN 300 330-1 issued by ETSI [3].

Tab. 1. Magnetic field limits at 10 m distance

Frequency [kHz]	H_{MAX} [dBμA/m]	H_{MAX} [μA/m]
83.0	42.0	125.9
101.4	42.0	125.9
121.6	58.8	871.0
134.0	58.4	831.8
145.7	37.7	76.7

The limits for radiated magnetic field measured at 10 m distance from locator antenna and for different working frequencies are shown in Tab. 1. These limits consider antenna radius r_{LT}=0.1 m.

3. MAGNETIC FIELD GENERATED BY LOCATOR

Transmitter antenna of locator generates magnetic field with intensity

$$H_L(x) = \frac{N_{LT} I_L S_{LT}}{2\pi\sqrt{(r_{LT}^2 + x^2)^3}} \qquad \text{[A/m]} \qquad (1)$$

where individual symbols denote:

- transmitter coil number of turns	N_{LT}=50
- diameter of transmitter coil	r_{LT}=0.1 m
- area of transmitter coil	S_{LT}=0.0314 m^2
- transmitter coil current	I_L=0,5 A
- distance from transmitter coil	x

These parameters were chosen so that limits given in Tab. 1 are fulfilled, i. e. $H_L(x)$=42 dBμA/m for x=10 m for all working frequencies (note: for frequency 145.7 kHz the limit is lowered to 37.7 dBμA/m). Dependence of intensity $H_L(x)$ on distance x is shown in next graph (Fig. 1) and if given limits must be fulfilled, the intensity cannot be influenced by any means.

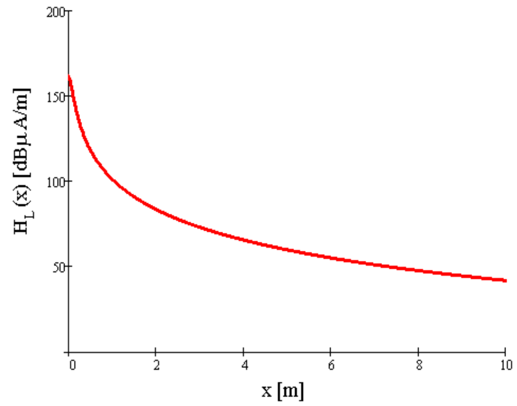

Fig. 1. Magnetic field intensity generated by locator.

4. VOLTAGE INDUCED INTO MARKER

The magnetic field with intensity given by (1) induces into marker voltage

$$U_M(x) = \mu\omega Q_M N_M S_M H_L(x) \quad [\mathrm{V}] \qquad (2)$$

where

- marker coil number of turns $N_M=35$
- marker area $S_M=0.0314\ \mathrm{m}^2$
- quality factor of LC circuit $Q_M=70$
- permeability $\mu=4\pi.10^{-6}$ H/m
- circular frequency $\omega=637$ krad/s

Next graph shows dependency of voltage $U_M(x)$ on distance x. At 1.5 m the voltage is 2.26 V and this value is sufficient for supplying the RFID chip but in distance x=3 m the voltage is insufficient (only 0.28 V). Ratio of these two values is

$$\frac{U_M(1{,}5)}{U_M(3)} = 7{,}96$$

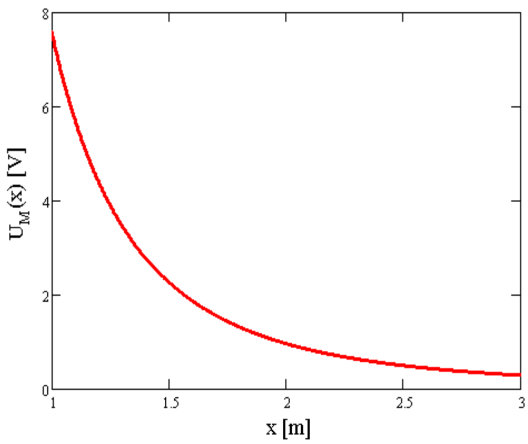

Fig. 2. Voltage induced into marker

and therefore for correct supplying of RFID chip at 3 m distance the induced voltage must be 8 times increased. Analysis of formula (2) shows that it can be done only by increasing of number of turns N_M and/or area S_M. The quality factor cannot be increased for the sake of tuned LC circuit parasitic features and of required frequency bandwidth, μ and ω are constant and $H_L(x)$ is limited by standard [3].

5. CHANGE OF COUPLING FACTOR BETWEEN MARKER AND LOCATOR COILS AND ITS INFLUENCE ON INDUCTIVITY

The coupling factor depends on geometrical arrangement of both coils (Fig. 4) and is given by formula (3) [4, 5], where r_M is marker coil radius and θ is angle between coils.

According to (3) the coupling factor at distance x=1.5 m is $k(1{,}5)=2{,}94.10^{-4}$ and for x=3 m the value of $k(3)=3{,}70.10^{-5}$, i. e. it is 8 times smaller (Fig. 3). If we want to keep the coupling factor at longer distance the marker radius r_M in (3) must be 4 times increased.

$$k(x) = \frac{r_{LT}^2 . r_M^2 . \cos\theta}{\sqrt{r_{LT} . r_M} . (r_{LT}^2 + x^2)^{\frac{3}{2}}} \quad [-] \qquad (3)$$

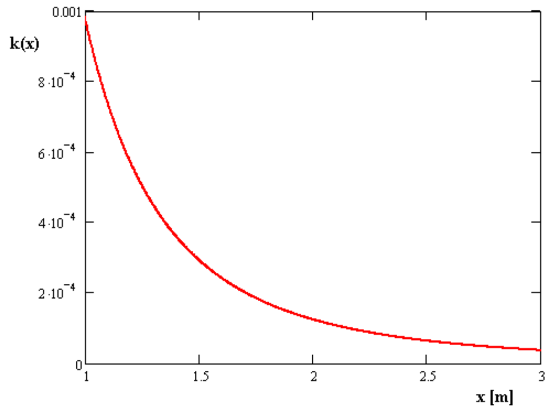

Fig. 3. Coupling factor

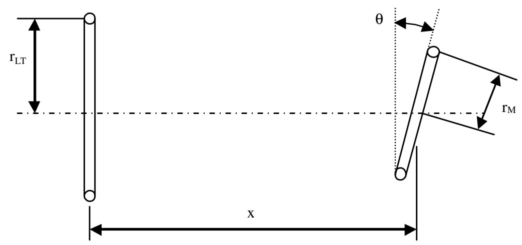

Fig. 4. Geometrical arrangement of coils.

The inductivity of circular coil is (according to [4])

$$L_M = \mu . N_M^{1,9} . r_M . \ln\left(\frac{r_M}{r_0}\right) \quad [\mathrm{H}] \qquad (4)$$

where r_0 is conductor radius. If the coil radius r_M is 4 times increased the inductivity is increased by factor 4.ln4 i. e. 5.55 times. If the original inductivity has to be kept, it must be compensated by number of turns N_M decreased by factor $5.55^{1/1.9}$ i. e. 2.46 times.

6. CONCLUSION

For doubling RFID marker read range from 1.5 m to 3 m these changes are needed:

- The marker diameter must be 4 times increased (from original value of 20 cm to 80 cm).
- Number of turns must be decreased 2.46 times (from original value of 35 to 14 turns).

Then the induced voltage (2) at distance 3 m will be 1.82 V. This is sufficient for correct supplying of the RFID chip. Neither the coupling factor (3) nor inductivity (4) will not be essentially changed. Experimental testing of big marker has not been performed yet and will be done in future.

Another question is practical usability of so big marker – manipulation, mechanical resistance, requirement of wide excavation etc. and price.

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